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A Comparative Study of Fracture Resistance of Various Intraradicular Devices at Different Angles of Load Application

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Keywords
intraradicular posts, angle of load, fracture resistance, threaded post, fiber post, positive locking post.

Abstract
Aims: Intraradicular posts are recommended to aid in the retention of artificial crowns and support the teeth by distributing intraoral forces along the roots. The purpose of this in vitro study was to compare fracture resistance of different types of endodontic posts viz threaded metal post, fiber post and the positive locking post and variance in regard to length, diameter and load application at different angles to simulate different positions of tooth in normal, prognathic and retrognathic conditions.

Materials and method: For the purpose of this study fifteen extracted human maxillary central incisors per parameter were selected randomly. All the teeth were sectioned transversely at cemento-enamel junction and the roots were endodontically treated. The following intraradicular retentive devices were selected and used in the specimen:

I.Stainless steel threaded posts of Mani EG make with diameters of:
A. 1.25mm with length of 9.5mm, 12mm and 14.5mm.
B. 1.45mm with 9.5mm, 12mm and 14.5mm.
C. 1.65mm with 9.5mm, 12mm and14.5mm.
II. Easy fiber posts of Dentsply make with diameter of:
A. 1.83mm with length of 9.5mm, 12mm and 14.5 mm.
B. 2.04mm with length of 9.5mm, 12mm and 14.5mm.
C. 2.22mm with length of 9.5mm, 12mm and 14.5mm
III. Meisinger's Wurzburger stift (Positive locking post) made of titanium with diameter of 4.5mm and maximum insertion

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depth of 2.75mm.
All of the preformed intraradicular posts were cemented with glass ionomer luting cement. Specimens were submitted to a compressive load in a universal testing machine, Instron to determine the fracture resistance. The failure load was recorded and analyzed between three subgroups. The results obtained were tabulated and subjected to statistical analysis for result.
Results: The results of the present study indicate that with increase in diameter of threaded posts, fracture resistance increased for all lengths. The highest fracture resistance was attained by highest diameter of 1.65mm and length of 14.5mm for all angles. Fiber posts exhibited decreasing fracture resistance as the diameters increased across all lengths. The results also indicate that with increase in length of threaded posts, fracture resistance increased across all diameters. The highest fracture resistance was obtained for length of 14.5mm. Fiber posts exhibited increasing fracture resistance with increase in length across all diameters. The results showed as the length increased, fracture resistance increased in threaded and fiber posts which signify that length is important for fracture resistance. But positive locking post with dimensions of length 2.75mm and diameter 4.5mm had higher fracture resistance irrespective of length and diameter of threaded post and fiber posts. This study confirmed that the angulation of loading is a factor apart from different lengths and diameters affecting the absolute failure loads measured in static tests. Statistically, the pooled average fracture resistance showed that increased from 450 through 1350 for all the post types used.
Conclusion: The threaded post which is made of stainless steel is more ductile and as diameter and length of the threaded post increased, the material gave the strength leading to higher fracture resistance. Fiber post which has modulus of elasticity similar to dentin depended upon the remaining dentin for fracture resistance and hence as the diameter increased fracture resistance decreased and as length increased fracture resistance increased. Positive locking post which is made of titanium is short in length and wider in diameter. It distributes stresses over a large area at the post tooth interface and hence provided highest fracture resistance.
The average pooled highest fracture resistances recorded at 900 and 700 angles showed that fiber post can be considered for use in retroganthic and prognathic situations while threaded post which recorded higher fracture resistance at 1350 can be used in class I situations. For normal, retrognathic and prognathic situations the choice of intraradicular device was positive locking post as it had the highest fracture resistance at all angles. All the posts performed better in normal followed by retrognathic and prognathic loads.

1. Introduction

Endodontically treated teeth present a high risk of biomechanical failure due to the loss of tooth substance resulting from preexisting decay and endodontic therapy[1]. In treating these teeth, intraradicular posts are recommended to aid in the retention of artificial crowns and support the teeth by distributing intraoral forces along the roots. Various designs of retentive devices have been used starting form Dowel and Davis crown, Richmond crown to preformed metal posts, threaded post, fiber post etc.

Porcelain pivot crowns were described in early 1800's by Dubois de Chemant. Majority of posts used earlier were metallic. They can be of various types- tapered, parallel, carbon, fiber, Wurzburger stift (positive locking post), threaded etc. Threaded posts depend primarily on engaging the tooth either through threads formed in dentin as the post is screwed into the root or through threads previously tapped into the dentin. It was found that cast post-and-cores and pre-fabricated metallic posts were reported to yield higher occurrence of catastrophic root fracture than fiber posts because of their higher modulus of elasticity[2] while other studies found has shown no significant difference of fracture modes between fiber and metallic posts.[3,4]

Recently in response to a need for tooth coloured posts, nonmetallic posts such as fiber posts are preferred over metallic posts.[1]. Earlier studies reported that carbon fiber post exhibited high fatigue strength, high tensile strength and a modulus of elasticity similar to dentin.[5,6,7,8,9,10]

The Wurzburger stift, a new post and core restoration system designed to eliminate the weak parts of post and core restorations and the associated problems. In contrast to conventional posts, the Wurzburger stift is a short and thick post, which no longer relies on cementation or luting for retention in the root, but on stress free positive locking, which it achieves by means of a post which can be spread into a predefined and congruent undercut cavity.

It was suggested that the post has to be three fourths the length of the root when treating long rooted teeth.[11] When average root length is encountered, post length is dictated by retaining 5mm of apical gutta-

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percha and extending the post to the gutta-percha.[12] Whenever possible, posts should extend at least 4mm apical to the bone crest to decrease stresses in dentin.[13,14,15] It was proved that post length was the most important factor affecting retention and post diameter was a secondary factor.[16]

It is the diameter of the dowel, which commonly contributes to the root fracture. “Conservationists,” advocates the narrowest diameter that allows the fabrication of a dowel to desired length with only minimal instrumentation of the canal after removal of gutta-percha. “Proportionists” recommends a dowel space with an apical diameter equal to one third the narrowest dimension of the root diameter at the end of the dowel space. “Preservationists” advises that at least 1mm of sound dentin should surround the entire surface of the dowel. Many factors, such as length, diameter, design and post material can influence the biomechanical behaviour of root filled teeth by modifying stress distribution and fracture resistance.[1,17]

The purpose of this in vitro study was comparison of the fracture resistances of threaded post, fiber post and the latest short positive locking post and variance in regard to length, diameter and load application at different angles to simulate different positions of tooth in normal, prognathic and retrognathic conditions.

2. Materials And Methods

For the purpose of this study fifteen extracted human maxillary central incisors per parameter were selected randomly with minimal carious involvement of the roots. All the teeth were sectioned transversely at cemento-enamel junction with the use of water cooled diamond rotary cutting bur fitted on an airotor handpiece running at a speed of 40000 rpm to prevent charring. The roots were endodontically treated up to number 40 master K file and were obturated with cold laterally condensed gutta-percha. To simulate the periodontal ligament, the root surface was marked 4mm below the sectioned surface and covered with 2 layers of adhesive tape. An aluminium cylinder with an internal diameter of 25mm was made to contain the auto polymerizing acrylic resin. They were filled with pourable resin mix and the roots covered were embedded in the soft resin. When the resin became rubbery, the tooth was removed from the acrylic resin. During the course of polymerization, the acrylic resin block was cooled in water to avoid deformation of the acrylic resin so that the embedded depth could remain unchanged and to avoid dehydration of the dentin. The adhesive tapes on the root were removed. Silicone impression material was mixed and injected into acrylic resin mold and the tooth was reinserted in the empty socket. Gutta percha from the root canal was removed according to the length of the post to be used by paeso reamer.

The following available intraradicular retentive devices were selected and were divided into three groups.(picture 1)

I.Stainless steel threaded posts of Mani EG make with diameters of :

A. 1.25mm with length of 9.5mm, 12mm and 14.5mm.

B. 1.45mm with 9.5mm, 12mm and 14.5mm.

C. 1.65mm with 9.5mm, 12mm and14.5mm.

II. Easy fiber posts of Dentsply make with diameter of :

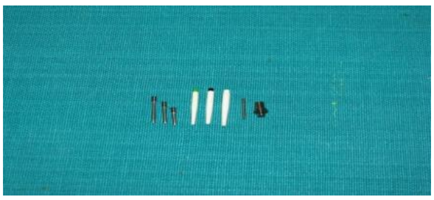
A. 1.83mm with length of 9.5mm, 12mm and 14.5 mm.

B. 2.04mm with length of 9.5mm, 12mm and 14.5mm.

C. 2.22mm with length of 9.5mm, 12mm and 14.5mm

III. Meisinger’s Wurzburger stift (Positive locking post) made of titanium with diameter of 4.5mm and maximum insertion depth of 2.75mm.

Picture 1: Threaded post, Fiber post, and Positive locking post



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All of the preformed intraradicular posts were cemented with glass ionomer luting cement. The coronal height of the post above the CEJ was standardized for all the subgroups. Midpoint of coronal height of the post above CEJ, i.e 2.5mm was marked and used as the point for the forces to be applied. Specimens were submitted to a compressive load in a universal testing machine, Instron. The load was applied at a crosshead speed of 0.5mm/min. Load applied on the lingual surface at angles.[18,19]

I.135^0 (fig 1, Picture 2) which is interincisal angle in class I occlusion as given by Steiner et al (1960);

II.90^0 (fig 2, Picture 2)

III. 70^0 (fig 3, Picture 3) (SNA angle: is the angle formed by the intersection of S.N plane and a line joining nasion and point A. This angle indicates the relative antero-posterior positioning of the maxilla in relation to the cranial base. The mean value is 82^0. A larger than normal value indicates that maxilla is prognathic, as in class II, while smaller value is suggestive of a retrognathic maxilla as in class III)

IV. 45^0 (fig 4, Picture 3)

The loading force, until the first drop of the load was observed and was determined as the failure load.(Picture 4,5,6) The failure load was recorded and analyzed between three subgroups. The failure modes of the specimens were also determined by visual inspection. The results obtained were tabulated and subjected to statistical analysis for result.

Figure 1:

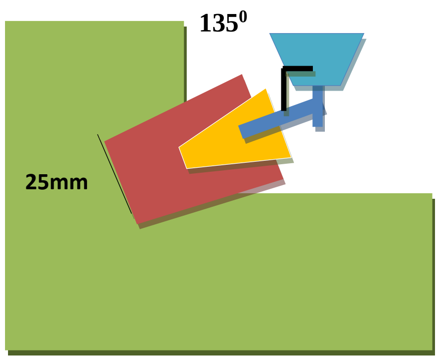


Figure 2:

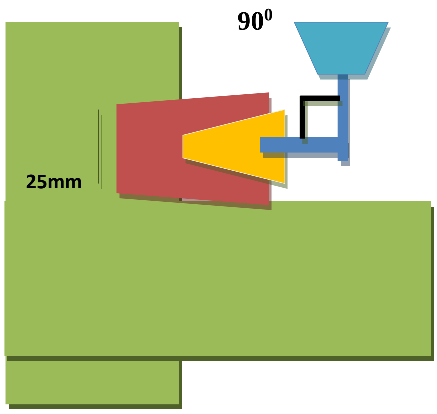


Figure 3:

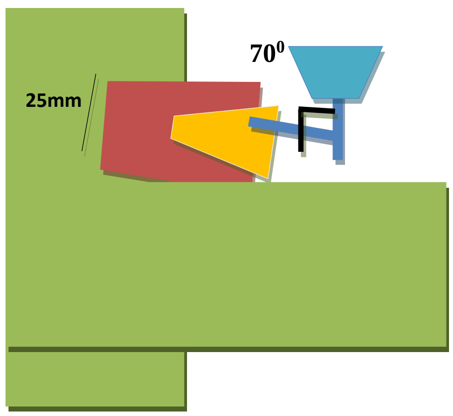
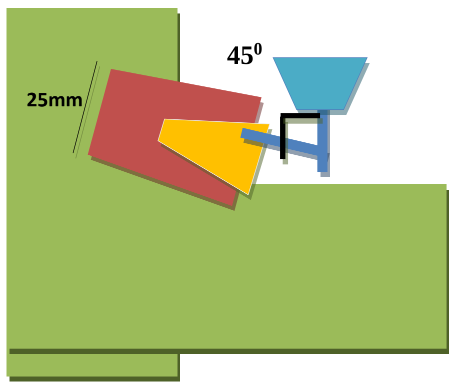


Figure 4:



Picture 2: Blocks prepared to receive cylinders for angles 135^0 and 90^0.

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Picture 3: Blocks prepared to receive cylinders for angles 70^0 and 45^0.

Picture 4: Insertion of specimen into tooth space in resin filled with polyvinyl siloxane

Picture 5: Loading of Threaded post

Picture 6: Failure of Fiber post specimen

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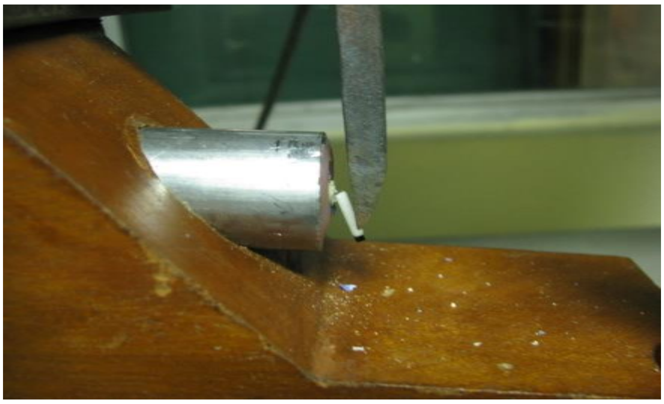

Statistical methods used

1. Students "t" tests for comparisons of two averages

   a) When sample figure are equal (n).

$$t_k = \frac{x_1 - x_2}{\sqrt{\frac{s_1^2 + s_2^2}{n}}}$$

When x_1, x_2 as the two average fracture resistance values to be compared,

S_1 & S_2 as the respective s.d. values

n = Sample Size and

r = d.f. = 2n-2

   b) For unequal sample sign (n_1 & n_2)

$$t_k = \frac{x_1 - x_2}{\sqrt{\frac{(n_1 - 1)\, s_1^2 + (n_2 - 1)\, s_2^2 \times (1/n_1 + 1/n_2)}{n_1 + n_2 - 2}}}$$

"t" value thus computed (by either method), were compared with the critical value of "t with R d.f. If the "t value was less than the critical value, it was treated as non significant (p>0.005). But, if the computed "t" value was greater than the critical value at 5% or 1% or 0.1% level, it was treated as significant at that level (i.e. p<0.05 or p<0.01 or p<0.001, as the case may be).

Abbrevations: CEJ: Cementoenamel junction; d.f: degree of freedom; k = d.f: degree of freedom; n: number of samples; N.S: Not Significant; P: Probability; S or S.D: Standard deviation; t: Student's "t" test; x: variables, comparison of averages.

3. Results and Analysis

A large variation in the results between the various combinations of post length, diameter and load at

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various angles was observed. Almost all specimens failed because of the following reasons:

a) root fracture in case of positive locking post.

b) combination of root fracture and shearing of post in case of fiber post

c) root fracture and deformation of threaded post.

Tables for different types of posts at different load angles have been made to observe the results.

Load at 45^0

Threaded post

Table No. 1: Comparison of the average fracture resistance of threaded posts of different lengths and diameters in Newtons when a load at 45^0 was applied.

Length (mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.25 (A1)**	**1.45 (B1)**	**1.65 (C1)**	**1.25 (A2)**	**1.45 (B2)**	**1.65 (C2)**	**1.25 (A3)**	**1.45 (B3)**	**1.65 (C3)**
Average (N)	83.16	85.1	88.5	84.5	90.32	93.06	90.52	92.24	94.7
S.D.	3.81	3.63	1.59	1.25	1.22	1.61	0.567	0.647	0.837

For the length 9.5mm, as the diameter increased from 1.25mm to 1.65mm fracture resistance increased. Similar pattern of increasing fracture resistances was also observed for lengths 12mm and 14.5mm. The highest fracture resistance was observed for diameter 1.65mm of 14.5mm length.

Table No. 2: Comparison of the average fracture resistance of threaded posts of different diameters within the same length when a load at 45^0 was loaded.

	A1 Vs B1	**A1 Vs C1**	**B1 Vs C1**	**A2 Vs B2**	**A2 Vs C2**	**B2 Vs C2**	**A3 Vs B3**	**A3 Vs C3**	**B3 Vs C3**
" t"	0.82	2.89	1.92	7.45	9.39	3.03	4.47	9.24	5.20
" p"	N.S.	<0.05	0.09 N.S.	<0.001	<0.001	<0.002	<0.001	<0.001	<0.001

N.S. = Not significant (p>0.005)

For the length 9.5mm the average fracture resistance for the diameter 1.65mm was highest and it is significantly higher than of 1.25mm diameter (t=2.89, d.f = 8, p<0.05). But there was no significant difference between B1 and C1 and between A1 and B1. However comparison of average fracture resistance between A1 and C1 was found to be significant.

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For the length 12mm, the difference in the average fracture resistances between the diameters (viz. 1.25, 1.49 and 1.65mm) were significant as revealed by the "t" and "p" values. The "t' values were lowest between B2 and C2 and highest between A2 and C2.

Also, for the length 14.5mm, the highest average fracture resistance was for diameter 1.65mm followed by the diameter 1.45mm and 1.25mm. Here also, the difference between two average fracture resistances were significant (for A3 vs B3, t = 4.47, p<0.01; A3 vs C3: t=9.24, p<0.001 and for B3 vs C3: t= 5.20, p<0.001).

Table No. 3: Comparison of the average fracture resistances of threaded posts of different lengths having same diameter when a load at 45^0 was applied.

	A1 Vs A2	A1 Vs A3	A2 Vs A3	B1 Vs B2	B1 Vs B3	B2 Vs B3	C1 Vs C2	C1 Vs C3	C2 Vs C3
" t "	0.75	4.27	9.81	3.05	4.33	3.11	4.51	7.71	2.02
" p"	N.S.	<0.01	<0.001.	<0.02	<0.01	<0.02	<0.01	<0.001	N.S. (0.08)

For Diameter 1.25: The average fracture resistance for the length 14.5mm (A3) was highest and it was significantly greater than 12mm (A2) (t=9.81. d.f. = 8, p<0.001). It was also significantly greater than for length 9.5mm (A1) (t=4.27. d.f. = 8, p<0.01). However, the comparison of A1 and A2 i.e. of 9.5mm & 12mm length was not found to be significant (t=0.75, p=<0.05).

For Diameter 1.45: The average fracture resistance increased with the increase in length and the difference in average fracture resistances were significant as shown in the table3, B1 Vs.B2 (t=3.05, p<0.02); B2 vs. B3 (t=3.11, p= <0.02);B1 Vs. B3 (t=4.33, p=<0.01).

For Diameter 1.65: The average fracture resistance increased with the increase in length, C1 vs. C3 (t_8=4.51, p=<0.01); C1 vs. C3 (t_8=7.71, p<0.001); C2 vs. C3 (t=2.02; not significant at 5% level but significant at 8% level)

FIBER POST

Table No.4: Comparison of the average fracture resistance of fiber posts of different lengths and diameters in Newtons when a load at 45^0 was applied.

Length (mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.83 (A1)**	**2.04 (B1)**	**2.22 (C1)**	**1.83 (A2)**	**2.04 (B2)**	**2.22 (C2)**	**1.83 (A3)**	**2.04 (B3)**	**2.22 (C3)**

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Average (N)	98.6	87.46	72.28	99.08	88.62	73.14	99.92	89.16	74.14
S.D.	0.98	1.307	1.99	0.476	0.712	1.228	0.779	0.555	0.763

The average fracture resistance for each length was highest for diameter 1.83 and it decreased with the increase in diameter. The average fracture resistance for a particular diameter was highest for the highest length and lowest for the lowest length.

Table No. 5: Comparison of the average fracture resistance of fiber posts of different diameters within the same length when a load at 45^0 was loaded.

	A1 Vs B1	**A1 Vs C1**	**B1 Vs C1**	**A2 Vs B2**	**A2 Vs C2**	**B2 Vs C2**	**A3 Vs B3**	**A3 Vs C3**	**B3 Vs C3**
" t"	**15.26**	**26.53**	**14.25**	**27.31**	**43.97**	**24.39**	**25.15**	**52.86**	**35.6**
"p"	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

All the "t "values (d.f. = 8) were highly significant (p=<0.001). Highest "t" value was observed between A3 and C3 and lowest "t" value was observed between B1 and C1.

Table No. 6: Comparison of the average fracture resistances of fiber posts of different lengths having same diameter when a load at 45^0 was applied.

	A1 Vs A2	**A1 Vs A3**	**A2 Vs A3**	**B1 Vs B2**	**B1 Vs B3**	**B2 Vs B3**	**C1 Vs C2**	**C1 Vs C3**	**C2 Vs C3**
" t "	**0.99**	**2.35**	**2.06**	**1.74**	**2.68**	**1.34**	**0.82**	**1.95**	**1.55**
" p"	**N.S.**	**<0.05**	**0.08**	**N.S.**	**<0.05**	**N.S.**	**N.S.**	**0.09**	**N.S.**

The average fracture resistance between diameters of different lengths viz A1 vs. A2; B1 vs. B2; C1 vs. C2

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do not differ significantly. But A1 differed significantly from A3 (t=2.35, d.f. = <0.05) and B1 differed significantly from B3 (t=2.68, p<0.05)

Positive locking post

Data of positive locking post with insertion depth of 2.75mm length and 4.5mm diameter. The average fracture resistance recorded when load was applied at 45^0 for positive locking post was 119.1N with S.D. 0.255. This average fracture resistance of positive locking post was highest for the load at 45^0 followed by the average fracture resistance value for 1.83mm diameter with length14.5mm for the fiber post. The difference is 19.98N which was highly significant (t= 54.51, d.f. =<0.001).

LOAD at 70^0:

Threaded Post

Table No. 7: Comparison of the average fracture resistance of threaded posts of different lengths and diameters in Newtons when a load at 70^0 was applied.

Length (mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.25 (A1)**	**1.45 (B1)**	**1.65 (C1)**	**1.25 (A2)**	**1.45 (B2)**	**1.65 (C2)**	**1.25 (A3)**	**1.45 (B3)**	**1.65 (C3)**
Average (N)	**88.02**	**90.18**	**91.52**	**89.36**	**92.58**	**94.06**	**91.44**	**94.24**	**95.62**
S.D.	**0.259**	**0.638**	**0.476**	**0.631**	**0.672**	**0.744**	**0.727**	**0.581**	**0.61**

Significant (t=54.51d.f. =8, p<0.001)

For the length 9.5mm, as the diameter increased from 1.25mm to 1.65mm fracture resistance increased. Similar pattern of increasing fracture resistances were also observed for lengths 12mm and 14.5mm. The highest fracture resistance was observed for diameter 1.65mm of 14.5mm length.

Table No. 8: Comparison of the average fracture resistance of threaded posts of different diameters within the same length when a load at 70^0 was loaded.

	A1 Vs B1	**A1 Vs C1**	**B1 Vs C1**	**A2 Vs B2**	**A2 Vs C2**	**B2 Vs C2**	**A3 Vs B3**	**A3 Vs C3**	**B3 Vs C3**
“t“	7.01	14.44	3.76	7.81	10.77	3.30	6.73	9.84	3.66
“p”	<0.001	<0.001	<0.01	<0.001	<0.001	<0.02	<0.001	<0.001	<0.01

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All the differences were significant. It indicated that for each length (viz. 9.5, 12 and 14.5mm) increase in diameter produced significant increase in average fracture resistance.

Table No. 9: Comparison of the average fracture resistances of threaded posts of different lengths having same diameter when a load at 70^0 was applied.

	A1 Vs A2	**A1 Vs A3**	**A2 Vs A3**	**B1 Vs B2**	**B1 Vs B3**	**B2 Vs B3**	**C1 Vs C2**	**C1 Vs C3**	**C2 Vs C3**
“ t “	4.39	9.91	2.51	5.79	10.52	4.18	6.43	11.85	3.84
“ p”	<0.01	<0.001	<0.05	<0.001	<0.001	<0.01	<0.001	<0.001	<0.01

All the “t” values were significant because there was increase in average fracture resistance due to increase in length for a given diameter.

Fiber post:

Table No. 10: Comparison of the average fracture resistance of fiber posts of different lengths and diameters in Newtons when a load at 70^0 was applied.

Length(mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.83 (A1)**	**2.04 (B1)**	**2.22 (C1)**	**1.83 (A2)**	**2.04 (B2)**	**2.22 (C2)**	**1.83 (A3)**	**2.04 (B3)**	**2.22 (C3)**
Average (N)	101.74	95.98	84.98	103.5	100.64	89.14	104.98	101.92	90.64
S.D.	0.913	1.026	0.904	0.718	0.631	0.532	0.593	0.217	0.555

For each given length the highest average fracture resistance was for the diameter 1.83 and it reduced with the increase in diameter from 2.04 to 2.22. The average fracture resistance for a particular diameter was highest for the highest length and reduced with the reducing length.

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Table No. 11: Comparison of the average fracture resistance of fiber posts of different diameters within the same length when a load at 70^0 was loaded.

	A1 Vs B1	**A1 Vs C1**	**B1 Vs C1**	**A2 Vs B2**	**A2 Vs C2**	**B2 Vs C2**	**A3 Vs B3**	**A3 Vs C3**	**B3 Vs C3**
“ t “	9.38	29.17	17.99	6.69	35.93	31.16	9.04	39.48	42.33
“ p”	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

All the “t” values were highly significant. Thus for a given length the average fracture resistance decreased significantly with increase in diameter. The highest “t” value was between B3 and C3 and lowest “t” value between A2 and B2.

Table No. 12:

Comparison of the average fracture resistances of fiber posts of different lengths having same diameter when a load at 70^0 was applied.

	A1 Vs A2	**A1 Vs A3**	**A2 Vs A3**	**B1 Vs B2**	**B1 Vs B3**	**B2 Vs B3**	**C1 Vs C2**	**C1 Vs C3**	**C2 Vs C3**
“ t “	3.39	6.65	3.55	8.65	12.67	4.29	8.87	11.93	4.36
“ p”	<0.02	<0.001	0.01	<0.001	<0.001	<0.01	<0.001	<0.001	<0.01

All the “t” values were significant. For a given diameter, increase in length (from 9.5 to 12 to 14.5mm) significantly increased the average fracture resistance, highest being between B1 and B3 and lowest being between A1 and A2

Positive Locking Post

The average fracture resistance recorded for positive locking post when load was applied at 70^0 was 124.88N with S.D: 0.981

As in load at 45^0, here also, when load was applied at 70^0 the average fracture resistance recorded for positive locking post was significantly higher compared to all other average fracture resistances of threaded post and fiber post. The next highest average fracture resistance compared was 104.98N for length 14.5mm and diameter 1.83mm of fiber post. And the difference between this average fracture resistances was 19.90N which was highly significant (t= 38.81, d.f. =8, p<0.001).

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C. **Load at 90^0** **Threaded Post**

Table No.13:

Comparison of the average fracture resistance of threaded posts of different lengths and diameters in Newtons when a load at 90^0 was applied.

Length(mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.25 (A1)**	**1.45 (B1)**	**1.65 (C1)**	**1.25 (A2)**	**1.45 (B2)**	**1.65 (C2)**	**1.25 (A3)**	**1.45 (B3)**	**1.65 (C3)**
Average (N)	91.6	95.52	98.36	91.92	96.1	101.02	92.84	97.7	102.36
S.D.	0.358	0.567	1.36	0.311	0.316	0.444	0.607	0.583	0.518

For the length 9.5mm, as the diameter increased from 1.25mm to 1.65mm fracture resistance increased. Similar pattern of increasing fracture resistances was also observed for lengths 12mm and 14.5mm. The highest fracture resistance was observed for diameter 1.65mm of 14.5mm length.

Table No.14: Comparison of the average fracture resistance of threaded posts of different diameters within the same length when a load at 90^0 was loaded

	A1 Vs B1	**A1 Vs C1**	**B1 Vs C1**	**A2 Vs B2**	**A2 Vs C2**	**B2 Vs C2**	**A3 Vs B3**	**A3 Vs C3**	**B3 Vs C3**
" t "	14.54	11.45	4.31	21.08	37.54	20.19	12.91	26.68	13.36
" p"	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

As in previous tables, with the increase in diameter, average fracture resistance increased significantly for each length. [for B1 vs. C1, the "t" value is significant at 1% level and in all other comparisons, "t" values were significant at 0.1% level]

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Table No. 15: Comparison of the average fracture resistances of threaded posts of different lengths having same diameter when a load at 90^0 was applied.

	A1 Vs A2	**A1 Vs A3**	**A2 Vs A3**	**B1 Vs B2**	**B1 Vs B3**	**B2 Vs B3**	**C1 Vs C2**	**C1 Vs C3**	**C2 Vs C3**
" t "	3.58	5.33	3.02	2.34	5.99	5.40	4.16	6.15	4.39
" p"	<0.01	<0.001	<0.02	<0.05	<0.001	<0.001	<0.01	<0.001	<0.01

"t" values are significant for same diameter of different lengths. Highest "t" value was between C1 and C3 and lowest was between B1 and B2. For a given diameter, average fracture resistance increased, though slightly, with the increase in length.

Fiber Post

Table No. 16: Comparison of the average fracture resistance of fiber posts of different lengths and diameters in Newtons when a load at 90^0 was applied.

Length(mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.83 (A1)**	**2.04 (B1)**	**2.22 (C1)**	**1.83 (A2)**	**2.04 (B2)**	**2.22 (C2)**	**1.83 (A3)**	**2.04 (B3)**	**2.22 (C3)**
Average (N)	102.32	98.06	90.86	103.46	99.86	93.28	104.78	100.8	95.6
S.D.	0.763	0.48	0.586	0.518	0.921	0.841	0.563	1.0	0.83

Increase in length was associated with the increase in average fracture resistance values, but, for a given length increase in diameter was associated with decrease in the average fracture resistance values. Highest average fracture resistance was obtained for diameter 1.83mm with length 14.5mm and the lowest average fracture resistance was obtained for diameter 2.22mm with length 9.5mm.

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Table No. 17: Comparison of the average fracture resistance of fiber posts of different diameters within the same length when a load at 90^0 was loaded

	A1 Vs B1	A1 Vs C1	B1 Vs C1	A2 Vs B2	A2 Vs C2	B2 Vs C2	A3 Vs B3	A3 Vs C3	B3 Vs C3
" t "	10.52	26.64	21.25	7.62	23.05	11.80	7.75	20.47	8.95
" p"	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

All the "t" values were highly significant (p=<0.001). Highest "t' value was between A1 and C1. Lowest "t" value was between A2 and B2.

Table No. 18: Comparison of the average fracture resistances of fiber posts of different lengths having same diameter when a load at 90^0 was applied.

	A1 Vs A2	A1 Vs A3	A2 Vs A3	B1 Vs B2	B1 Vs B3	B2 Vs B3	C1 Vs C2	C1 Vs C3	C2 Vs C3
" t "	2.76	5.80	3.86	3.88	5.52	1.55	5.28	10.43	4.39
" p"	<0.05	<0.001	<0.01	<0.01	<0.001	N.S.	<0.001	<0.001	<0.01

Only difference in the average fracture resistance between length 12.5mm and 14.5mm for diameter 1.45mm (i.e. B2 & B3) did not differ significantly (t=1.55, d.f. =8, p>0.05). All other comparisons between the average fracture resistances showed significant results. Highest "t" value was between C1 and C3 and lowest between B2 and B3.

Positive Locking Post:

The average fracture resistance for positive locking post recorded when load was applied at 90^0 was 136.76N with S.D. 0.669.

The average fracture resistance of positive locking post when load was applied at 90^0 was highest when compared to the average fracture resistances of the threaded post and fiber post. The next average fracture resistance nearest to this was 104.78N with diameter 1.25mm and length 14.5mm of fiber post. And the difference 136.76N – 104.78N = 31.98N was highly significant (t=81.79, d.f. = 8, p=<0.001).

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Load at 135^0

Threaded Post

Table No.19: Comparison of the average fracture resistance of threaded posts of different lengths and diameters in Newtons when a load at 135^0 was applied.

Length(mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.25 (A1)**	**1.45 (B1)**	**1.65 (C1)**	**1.25 (A2)**	**1.45 (B2)**	**1.65 (C2)**	**1.25 (A3)**	**1.45 (B3)**	**1.65 (C3)**
Average (N)	104.02	106.54	108.08	106.4	109.06	111.56	108.84	112.32	116.66
S.D.	0.626	0.643	0.545	0.90	1.106	0.948	0.713	1.018	0.658

For the length 9.5mm, as the diameter increased from 1.25mm to 1.65mm fracture resistance increased. Similar pattern of increasing fracture resistances was also observed for lengths 12mm and 14.5mm. The highest fracture resistance was observed for diameter 1.65mm of 14.5mm length.

Table No.20: Comparison of the average fracture resistance of threaded posts of different diameters within the same length when a load at 135^0 was loaded

	A1 Vs B1	**A1 Vs C1**	**B1 Vs C1**	**A2 Vs B2**	**A2 Vs C2**	**B2 Vs C2**	**A3 Vs B3**	**A3 Vs C3**	**B3 Vs C3**
" t "	6.28	10.94	4.19	4.17	8.83	3.84	6.26	18.02	8.01
" p"	<0.001	<0.001	<0.01	<0.01	<0.001	<0.01	<0.001	<0.001	<0.001

As earlier noticed, the average fracture resistance value increased significantly as diameter increased and as length increased. Highest "t" values was obtained between A3 and C3 and lowest was between B2 and C2.

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Table No. 21: Comparison of the average fracture resistances of threaded posts of different lengths having same diameter when a load at 135^0 was applied.

	A1 Vs A2	**A1 Vs A3**	**A2 Vs A3**	**B1 Vs B2**	**B1 Vs B3**	**B2 Vs B3**	**C1 Vs C2**	**C1 Vs C3**	**C2 Vs C3**
" t "	4.85	11.36	4.75	4.40	10.73	4.85	7.12	22.45	9.88
" p"	<0.01	<0.001	<0.01	<0.01	<0.001	<0.01	<0.001	<0.001	<0.001

Difference in the average fracture resistances of same diameter for different lengths were found to be statistically significant for threaded post at 135^0. Highest "t" value was obtained between C1 and C3 and lowest was between B1 and B2.

Fiber Post :

Table No.22: Comparison of the average fracture resistance of fiber posts of different lengths and diameters in Newtons when a load at 135^0 was applied.

Length(mm)	**9.5**			**12**			**14.5**		
Diameter (mm)	**1.83 (A1)**	**2.04 (B1)**	**2.22 (C1)**	**1.83 (A2)**	**2.04 (B2)**	**2.22 (C2)**	**1.83 (A3)**	**2.04 (B3)**	**2.22 (C3)**
Average (N)	108.98	101.24	97.12	111.5	103.3	99.52	116.46	106.66	103.12
S.D.	0.476	0.727	0.54	0.725	0.707	0.709	0.997	0.560	0.576

For a given length, average fracture resistance values decreased as diameter increased. However, increased length was associated with increase in average fracture resistance value. The average fracture resistance for each length was highest for diameter 1.83 and it decreased with the increase in diameter. The average fracture resistance for a particular diameter is highest for the highest length and lowest for the lowest length.

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Table No.23: Comparison of the average fracture resistance of fiber posts of different diameters within the same length when a load was applied at 135^0.

	A1 Vs B1	A1 Vs C1	B1 Vs C1	A2 Vs B2	A2 Vs C2	B2 Vs C2	A3 Vs B3	A3 Vs C3	B3 Vs C3
" t "	19.92	36.84	10.17	18.11	26.42	8.44	19.16	25.91	9.85
" p"	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

All the "t" values were highly significant (p<0.001) indicating significant decrease in average fracture resistance values in each length for increasing diameters as in earlier tables. Highest "t" value was obtained between A1 and C1 and lowest "t" value was between B2 and C2.

Table No. 24: Comparison of the average fracture resistances of fiber posts of different lengths having same diameter when a load at 135^0 was applied.

	A1 Vs A2	A1 Vs A3	A2 Vs A3	B1 Vs B2	B1 Vs B3	B2 Vs B3	C1 Vs C2	C1 Vs C3	C2 Vs C3
" t "	6.50	15.14	8.99	4.54	13.21	8.33	6.02	16.99	8.81
" p"	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001

All the fracture resistance recorded between same lengths were found to be statistically significant for fiber post at 135^0. Highest "t" value was obtained between the average fracture resistances of C1 and C3 and lowest between B1 and B2.

Positive Locking Post:

The average fracture resistance for positive locking post recorded when load was applied at 135^0 was 175.18N with S.D. 1.248

This average fracture resistance value of positive locking post was the highest amongst all the other averages of fiber post, threaded Post when load was applied at 135^0. The next highest value was 116.46N for fiber post with diameter 1.83mm and for 14.5mm length. The difference (175.18N – 116.46N = 58.72N) was highly significant. (t = 82.22, d.f. = 8, p<0.001) Highest average fracture resistance recorded by intraradicular devices when load was applied at 45^0,70^0,90^0 and 135^0.

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The highest average fracture resistance value was obtained when load was applied at 135^0 and the next highest average fracture resistance value obtained was when load was applied at 90^0(The difference, 175.18N – 136.76N = 38.42N, was highly significant (t=60.67, d.f. = 8, p<0.001) followed by when load was applied at 70^0 and 45^0.

Thus, the positive locking post having 2.75mm length and 4.5mm diameter provided the highest fracture resistance when load was applied at 135^0 angle.

Table No.25: Comparison of the pooled average fracture resistances of threaded post, fiber post and positive locking post when load was applied at 45^{0,} 70^0, 90^0 and 135^0. This table also shows the comparison of the average fracture resistance between threaded post, fiber post and positive locking post over variation in load angles. (Newtons)

	In Degree			
	Load at 45	**Load at 70**	**Load at 90**	**Load at 135**
Average	119.1N	124.88N	136.76N	175.18N
S.D.	0.255	0.981	0.669	1.248

Load at: (In Degree)	Threaded post I N=45		Fibre Post II N=45		Positive Locking Post III N=5		Comparison of average fracture resistances					
							I vs II		I vs III		II vs III	
	Average	S.D.	Average	S.D.	Average	S.D.	t	p	t	p	t	p
45	88.52	11.3	86.93	10.86	119.1	0.255	0.68	N.S.	6.00	<0.001	6.56	<0.001
70	91.89	2.43	97.06	6.886	124.88	0.981	4.75	<0.001	29.86	<0.001	8.94	<0.001
90	96.33	3.79	98.78	4.563	136.76	0.669	2.77	<0.01	23.6	<0.001	18.4	<0.001
135	109.28	3.79	105.32	5.91	175.18	1.248	4.83	<0.001	38.72	<0.001	26.1	<0.001

Only for the load at 45^0, the pooled average fracture resistance values in respect to threaded post and that of fiber post did not differ significantly (t=0.68, d.f. = 48, p>0.05) [this is due to comparatively high S.D. value]

Against all other angular load viz, 70^0 to 135^0, there was significant variation in average fracture resistance values pooled for threaded post and fiber post. The pooled average fracture resistance values for fiber post when load was applied at 70^0 and 90^0 was higher than the pooled average fracture resistances of threaded post. However, for load at 135^0, the pooled average fracture resistance for threaded post was significantly higher compared to that of the average fracture resistance of fiber post. (t=4.83, d.f. =44, p<0.001)

For all angles when the load was applied, the average fracture resistance of positive locking post was significantly much higher compared to the average fracture resistance values recorded for threaded post and fiber posts.

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Table No. 26 : Comparison of the pooled average fracture resistance for each post as angular load increased from 45^0 to 135^0. This table also shows comparison of the average fracture resistances between various load angles of threaded post, fiber post and positive locking post.

Post Type	Pooled average by load angle In Degree				45^0 vs 70^0		70^0 vs 90^0		90^0 vs 1350	
	45	70	90	135	"t"	"p"	"t"	"p"	"t"	"p"
Threaded	88.52	91.89	96.33	109.28	1.96	N.S	6.62	<0.001	12.75	<0.001
Fiber	86.93	97.06	98.78	105.32	5.28	<0.001	1.40	N.S	5.88	<0.001
Positive Lock	119.10	124.88	136.76	175.18	12.75	<0.001	22.37	<0.001	60.67	<0.001

The pooled average fracture resistance (based on 45 samples for threaded and fiber post and only 5 samples for positive lock type) increased from 45^0 through 135^0 for threaded post, fiber post and positive locking post. The incremental increase in average fracture resistance was not significant (p>0.005) for threaded post from 45^0 to 70^0 and for fiber post from 70^0 to 90^0. All other increase in increments were significant (p<0.001).

4. Discussion

The purpose of this in vitro study was to compare fracture resistance of different types of endodontic posts viz threaded metal post, fiber post and the positive locking post and variance in regard to length, diameter and load application at different angles to simulate different positions of tooth in normal, prognathic and retrognathic conditions.

Charts showing fractures resistance of threaded post with different lengths and diameters at various angles of load application.

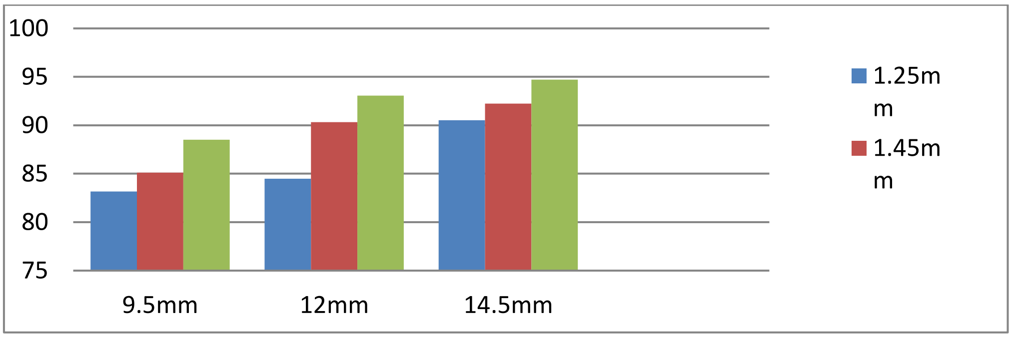

Chart 1: Average Fracture resistance at load 45^0.

X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents diameter in mm.

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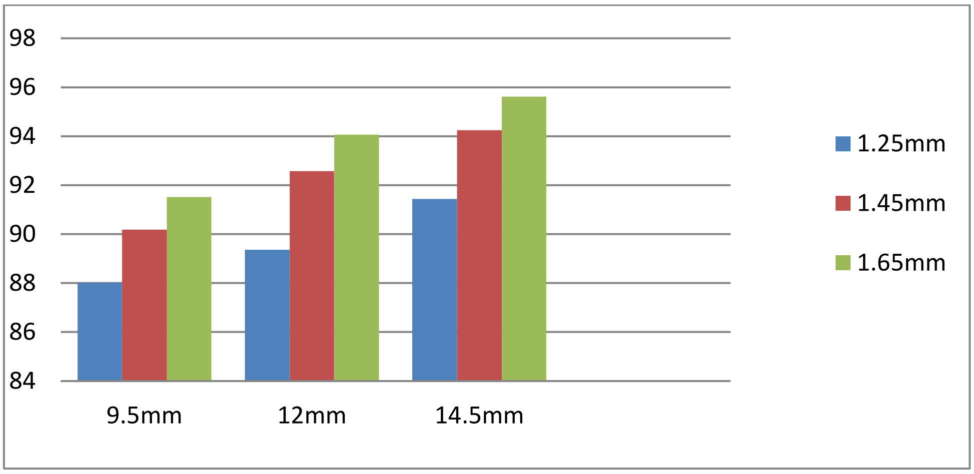

Chart 2: Average Fracture resistance at load 70^0.

X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents diameter in mm.

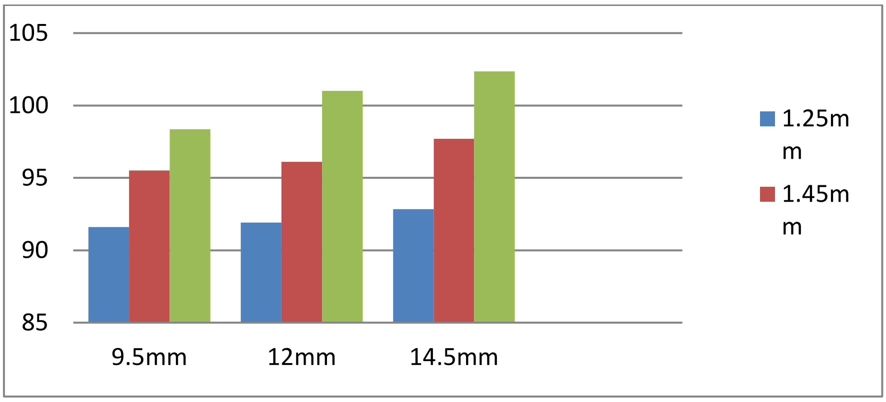

Chart 3: Average Fracture resistance at load 90^0.

X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents diameter in mm.

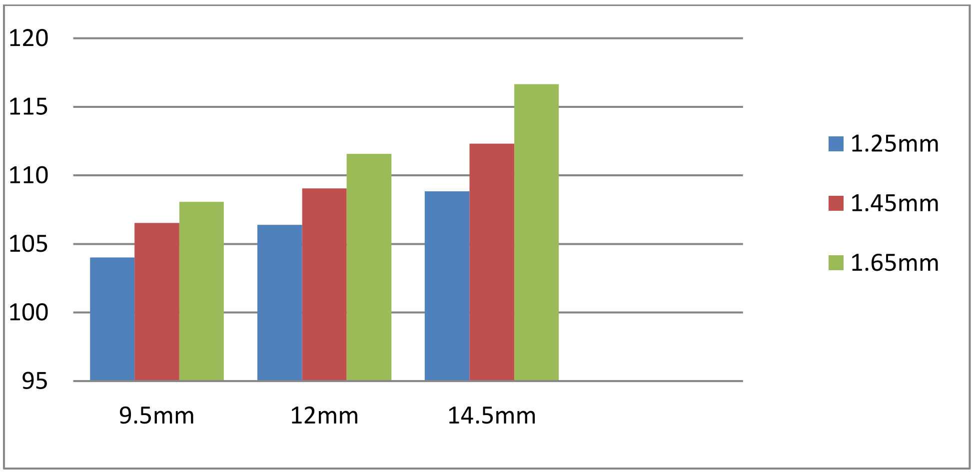

Chart 4: Average Fracture resistance at load 135^0.

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X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents diameter in mm.

The results of the present study in charts 1, 2, 3 and 4 indicate that with increase in diameter of threaded posts, fracture resistance increased for all lengths. The highest fracture resistance was attained by highest diameter of 1.65mm and length of 14.5mm for all angles. The results can be attributed to the stainless steel material which is ductile and as volume of post increased fracture resistance increased. These results are in accordance with the results of previous suudies where the mean minimum strength for thinnest post was significantly lower than that of mean maximum strength obtained from those of the thickest post.[21,22,23]

Charts showing fractures resistance of fiber post with different lengths and diameters at various angles of load application.

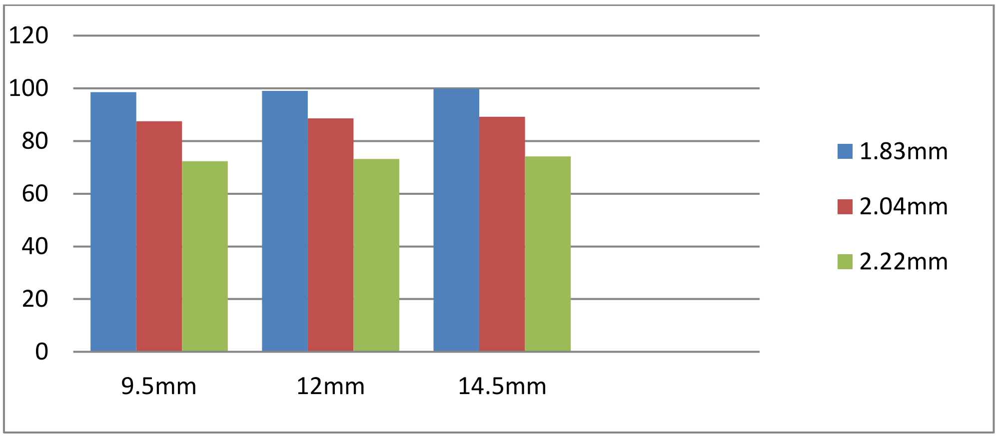

Chart 5: Average Fracture resistance at load 45^0.

X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents diameter in mm.

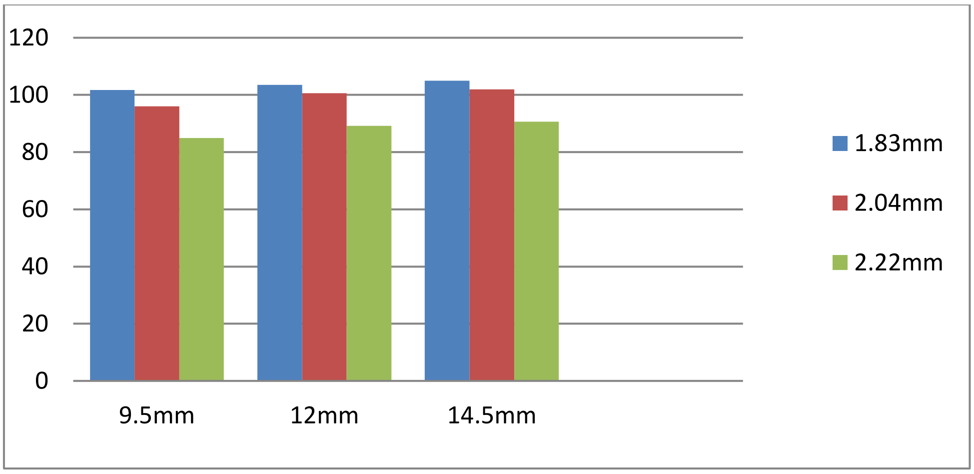

Chart 6: Average Fracture resistance at load 70^0.

X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents diameter in mm.

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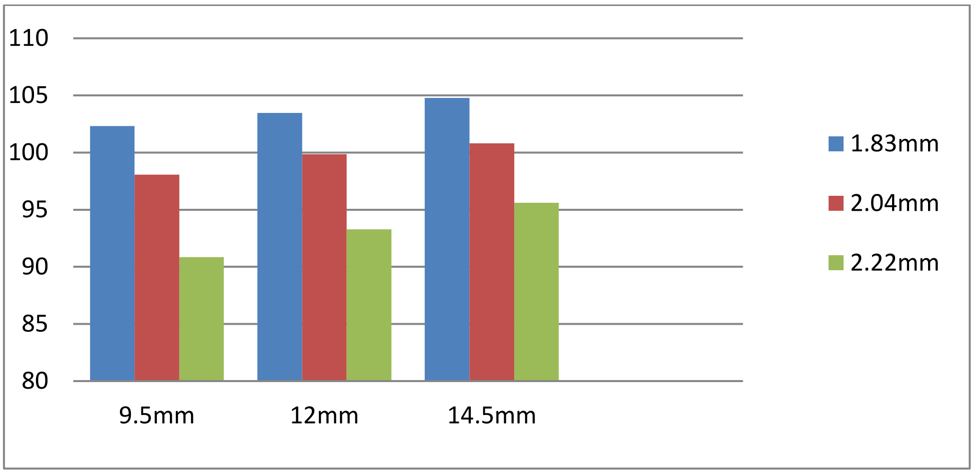

Chart 7: Average Fracture resistance at load 90^0.

X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents diameter in mm.

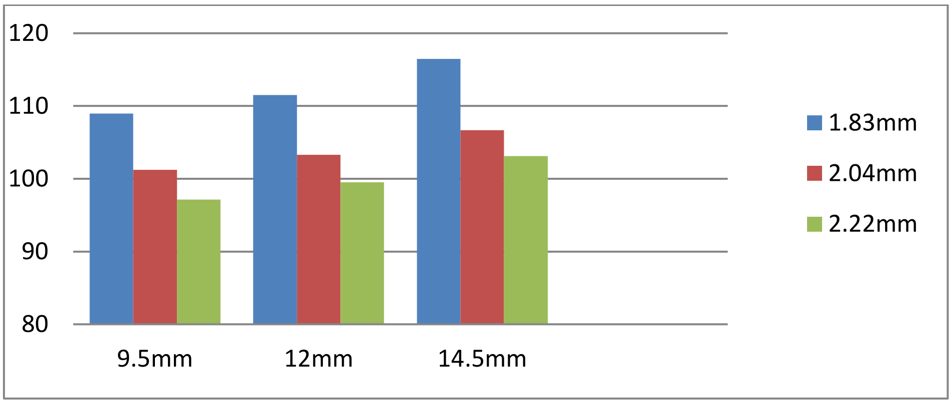

Chart 8: Average Fracture resistance at load 135^0.

X – axis represents length in mm; Y – axis represents fracture resistance in newtons. Green, red and blue bars represent diameter in mm.

Fiber posts in charts 5, 6, 7 and 8 exhibited decreasing fracture resistance as the diameters increased across all lengths and these results are comparable to previous studies.[24]

The results of the present study in charts 1, 2, 3, and 4 indicate that with increase in length of threaded posts, fracture resistance increased across all diameters. The highest fracture resistance was obtained for length of 14.5mm. These results are in accordance with the results of previous studies.[21,25]

Fiber posts in charts 5, 6, 7 and 8 exhibited increasing fracture resistance with increase in length across all diameters and these results are comparable to earlier studies.[26,27]

The results in this in vitro study indicated that as the length increased, fracture resistance increased in threaded and fiber posts which signify that length is important for fracture resistance. But positive locking post with dimensions of length 2.75mm and diameter 4.5mm had higher fracture resistance irrespective of length and diameter of threaded post and fiber posts which can be compared to results of David C. Holmes et al (1996)[28] study where he found that peak shear stresses elevated as length of the post decreased. All the specimens cemented with positive locking posts having insertion depth of 2.5mm failed due to root fracture and this can be supported by a study of Necdet Adanir et al (2008) who demonstrated that

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root fracture under significantly lower loading forces for posts shorter than clinical crown length.[25]

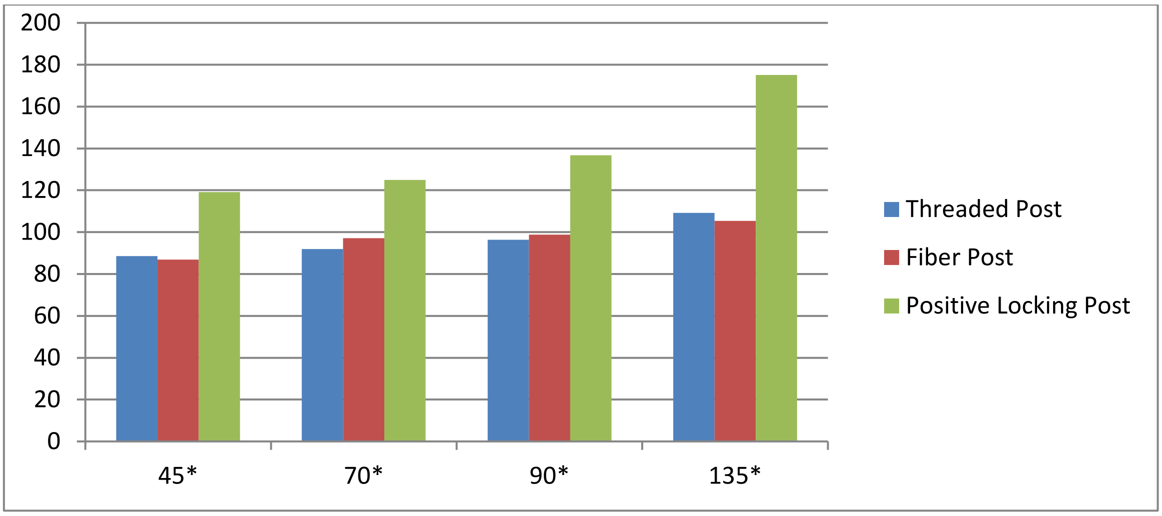

Chart 9: Pooled average fracture resistance when load applied at various angles for different types of posts.

X – axis represents load at angle in degrees; Y – axis represents fracture resistance in newtons. Green, red and blue bars represents threaded post, fiber post and positive locking post.

The present study confirmed that the angulation of loading is a factor apart from different lengths and diameters affecting the absolute failure loads measured in static tests. Statistically, the pooled average fracture resistance shown in chart 9 increased from 45^0 through 135^0 for all the post types used. This result are consistent with earlier studies[29] where significant differences in fracture resistance of post-restored teeth were found as a result of differing load angles. The increments of increase in fracture resistance are not significant for threaded post from 45^0 to 70^0 and for fiber post from 70^0 to 90^0 as shown in table 26. All other increments are significant.

Threaded post presented with higher average fracture resistance at 135^0 than fiber post as shown in chart 9 and these results can be compared to results of previous studies.[30,31] They found metal posts having higher fracture loads than fiber posts. The highest fracture resistance recorded was for positive locking post at 135^0.

Maximum bite force in the anterior region ranges from 108 N (females) to 176 N (males).[32] The results in chart 4 shows that threaded post at 135^0 with diameter 1.65mm and 14.5mm length had the highest fracture resistance of 116.66N. The chart 8 results show that the fiber post with diameter 1.83mm and 14.5mm length registered 116.46N. Both these results show that the highest fracture resistance recorded was above the low end of force recorded in Helkimo et al. (1977) study.[32] The positive locking post made of titanium recorded 175.18N at 135^0, was closer to the highest force recorded. These results suggest that positive locking post though being short in length is capable of resisting higher forces recorded in human oral cavity.

Majority of failure in this in vitro study with metal posts, threaded posts and positive locking posts, were because of root fracture.

The pooled average fracture resistance recorded in chart 9 showed that for angle 45^0 results were not significant and these results can be supported by studies conducted earlier.[33] For 70^0 to 90^0, fiber post had higher fracture resistance compared to threaded post. As shown in chart 9, Positive locking post recorded fracture resistance values higher than threaded and fiber post for all angles from 45^0 to 135^0.

Several limitations must be taken into consideration when discussing the results of this study:

a) The results are based on an in vitro study and do not necessarily give information about the clinical situation;

b) luting of the posts were performed under ideal conditions;

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c) loading was done in static condition;

d) various luting cements were not used and

e) different tooth sizes and/or tooth structures may affect the results (although randomization was used to minimize these effects) as some teeth are more resistant to fracture because of their shape.

5. Summary and Conclusion

It is well known fact that stresses concentrate at the neck of the post tooth interface. The threaded post which is made of stainless steel is more ductile and as diameter and length of the threaded post increased, the material gave the strength leading to higher fracture resistance. However, fiber post which has modulus of elasticity similar to dentin depended upon the remaining dentin for fracture resistance and hence as the diameter increased fracture resistance decreased and as length increased fracture resistance increased. Positive locking post which is made of titanium is short in length and wider in diameter. It distributes stresses over a large area at the post tooth interface and hence provided highest fracture resistance.

The forces at 135^0 are more or less directed along the long axis of tooth compared to 90^0 and 70^0. The average pooled highest fracture resistances recorded at 90^0 and 70^0 angles showed that fiber post can be considered for use in retroganthic and prognathic situations while threaded post which recorded higher fracture resistance at 135^0 can be used in class I situations. For normal, retrognathic and prognathic situations the choice of intraradicular device was positive locking post as it had the highest fracture resistance at all angles. All the posts performed better in normal (135^0) followed by retrognathic(90^0 and 70^0) and prognathic(45^0) loads.

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